Interoffice Memo

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Subject : Booster and PAR Upgrades and Enhancements
To : R. Gerig
Copy to : G. Decker, L. Emery, R. Klaffky, O. Singh

Purpose:

The purpose of this memo is to list Booster and PAR improvements and upgrades. The improvements are focused on enhancing the SR as a light source and fully utilizing the injector machines for operations activities and research. Priorities are given in terms of short term (2003), mid term (2004), and long term (> 2004). The improvements range from almost completely developed and installed to only a partial concept. I don't mention improvements that involve software, such as automated injection tuning scripts, software upgrades or commissioning new operations modes. The information presented for each improvement include present status, new components, specifications, R&D required, and unknown aspects.

Near and mid term improvements and upgrades:

Complete new booster extraction septum spare. Complete a spare B:ES1 with "core out of vacuum". This septum should be more reliable and replacement in the event of failure should be eased due to the out of vacuum core design. Thermal drift may also be dramatically smaller than the existing septum.

- Present status: Magnet, thermal drift and shot to shot measurements need to be completed. Depending on the outcome of the thermal drift measurement we may decide to install it this year.
- New components: Septum magnet.
- Specifications: Same as present B:ES1.
- R&D required: None.
- Unknown aspects: None.

LTP BESOCM upgrade, Allows averaging over 60 seconds worth of pulses. The averaging should prevent spurious trips due to PAR kicker noise. The existing LTP BESOCM is presently hard wired to trip for any pulse > 1.3 nC.

- Present status: Design of new housing and supports for BESOCM transformer is required. Plan is to install in the April shutdown.
- New components: Electronics, mechanical supports and transformer housing.

- Specifications: New electronics allows averaging over 60 seconds.
- R&D required: None.
- Unknown aspects: None.

Preventative Maintenance, Anticipate and fix minor problems before they become severe.

- Present status: Par H2O hoses showing obvious signs of radiation damage. Grounding issues with PAR kickers/LTP BESOCM.
- New components: As needed.
- Specifications: None.
- R&D required: None.
- Unknown aspects: None.

Upgrade Current Regulation for Booster Main Ramped Supplies, Upgrade is for the presently used linear operations ramps. The dipole and quadrupole supply current ramps drift with line voltage. The drifts occur during SR standardization or SR RF system power changes. Most of the problem is with the dipole supply which has 180 Hz uncorrectable ripple of amplitude dI/I ~0.004 at the injection energy of 325 MeV. The line voltage drift causes the dipole dI/I >0.005 (180 Hz ripple + offset due to line voltage drift) which results in beam loss at injection. Increasing injection energy to > 400 MeV would reduce the dI/I error at injection due to 180 Hz ripple to ~0.002.

- Present status: Current regulators exist but are not implemented. An open question is weather the existing current regulators can be used to close the current feedback loop with the existing linear ramps. It may be easier to put the existing software feedback correction in the IOC. However, this would require that the two correction programs presently used be combined into one (fixramp and Bcontrol).
- New components: None.
- Specifications: Maintain dI/I < 0.003 for the dipole/quad current ramps at injection.
- R&D required: Implement closed loop current regulation using existing current regulators. Software development to combine fixramp + Bcontrol and put them on the IOC if current regulator implementation is not workable.
- Unknown aspects: Achievable bandwidth of closed loop current correction.

Implement booster corrector IOC ramptable loading Speed ramp table calculation and loading for faster orbit correction. This will allow controllaws for orbit feedback to operate at a specific ramp time (injection, extraction and anywhere in between). The IOC takes care of the details of updating AFG ramp tables after a current change is made.

- Present status: Idea has not been studied in detail yet.
- New components: Possible hardware changes to the corrector power supply system needed.

- Specifications: To be determined. Maximum corrector ramp slope needs to be specified.
- R&D required: Corrector controls software changes and studies required.
- Unknown aspects: Speed of IOC ramptable updates when a current change is requested.

Booster BPM timing upgrade, Configure booster bpm timing individually instead of in groups of 8 bpms. This upgrade will allow configuration of bpms for specific purposes (transverse/longitudinal injection controllaws, extraction bump correction, mid-ramp orbit correction).

- Present status: Proposal stage.
- New components: Individual timing card required for each bpm.
- Specifications: Allow the same bpm timing configuration as with presently used cards.
- R&D required: Develop a new timing card.
- Unknown aspects: None.

Booster BPM beam history upgrade, Most beam histories in the booster presently do not work. Two are presently used by routine operations to correct synchrotron oscillations at injection with controllaw. Other applications for the beam histories include betatron tune measurement and general instability studies.

- Present status: Existing plan is to upgrade identical beam histories in the storage ring. Proposal is to upgrade booster beam histories at the same time as storage ring.
- New components: Working beam history modules.
- Specifications: Same as existing beam histories that function.
- R&D required: None.
- Unknown aspects: None.

Upgrade PB, PTB and 5 to 8 booster injection point BPMs for single shot, These bpms will be used to control beam trajectory for direct injection using RF guns and PC gun. A part of this upgrade is to eliminate use of SCDU/MS modules for booster injection point bpms by the PB and BB lines of Leutl. The SCDU/MS modules require 4 shots minimum to update the x and y readings and therefore do not give single shot capability in the PB presently. It is also desired to have the ability to switch between SCDU/MS modules and single shot electronics for orbit control and injection applications for the booster injection point bpms.

- Present status: Diagnostics group has circuit designs for single shot capability.
- New components: Single shot electronics, switch for SCDU/MS mode and single shot mode for booster injection point bpms.
- Specifications: Same as LTP bpms.
- R&D required: Testing of single shot electronics with rf gun and PC gun beams.

- Unknown aspects: How well does single shot electronics work with booster button bpm signals generated by rf gun (10 ns) S-band pulses?

Booster tune measurement/bunch cleaning system upgrade, Bunch cleaning at injection (< 3 GeV) is needed for direct injection/subharmonic capture to insure bunch purity. Dedicated DSP based tune measurement will eliminate the need for existing VSA/extraction kicker pinger system which only gives the tunes at 25 ms intervals up the ramp. The ultimate goal is to integrate tune measurement and bunch cleaning systems where the tune measurement programs the drive frequency of the bunch cleaner.

- Present status: Bunch cleaning demonstrated in studies but inefficient (demonstrated keeping a single 2.8 ns 352 MHz bucket out of 10 ns rf gun pulse). Controls, fast rf switch chassis exist and were used with vertical bunch cleaning stripline installed in the booster to do the experiments. Chassis to select pickup and driver stripline configurations exists but does not function properly. Driver amplifiers do not work and tend to break easily.
- New components: Need two 100 W, 352 MHz cf, 10 MHz BW amplifiers for bunch cleaning. Need four 25 -50 W 352 MHz cf, 10 MHz BW amplifiers for tune measurement. Need to ramp the drive power for tune measurement amplifiers (use spare AFGs). Fast beam history, front-end electronics and DSP module with at least 200k turn data capacity for tune measurement.
- Specifications: Details beyond what is specified above to be determined with diagnostics and controls.
- R&D required: Tests of tune measurement/bunch cleaning separately and integrated as one system.
- Unknown aspects: Exactly how to integrate tune measurement/bunch cleaning systems.

Implement an independent rf source for the booster, Run the booster rf system at frequencies different from the SR. This will allow measurements of the dispersion, chromaticity and booster circumference without disrupting the SR beam. This source could also be used for subharmonic cavity commissioning/conditioning.

- Present status: Second rf source exists.
- New components: Misc cabling, possibly controls.
- Specifications: Identical to existing SR/Booster rf source. Must work with PAR rf system.
- R&D required: None.
- Unknown aspects: Timing/controls modification/P0 timing. Need to inject into same SR buckets and switch without dumping beam.

Implement a rapid waveguide switch for the booster RF, The purpose of this request is to switch between RF3 and RF5 in minutes instead of the present hours.

- Present status: This is an rf group R&D project at this time.

- New components: New high power waveguide shutter, new ACIS chassis and key switch.
- Specifications: Power level for shutter (see rf group).
- R&D required: High power shutter development.
- Unknown aspects: High power shutter reliability/durability.

Finish booster subharmonic capture design, This goal of this project is to achieve efficient direct injection from linac to booster (LS-297). The aim is capture the rf gun 2 beam with parameters 10 nC/pulse, 2 Hz, 8-10 ns 0.5 % total energy spread. Implicit in this request is that rf gun 1 will be upgraded to produce the same beam parameters and efficiency as rf gun 2. Subharmonic capture in the booster will remove the PAR from being absolutely required for SR injection to backup status.

- Present status: In the short term, test new RFMODE element in **elegant**. Work with the rf group on a design of a 6^{th} subharmonic capture cavity (58 MHz, 400 kV, LS-26, LS-28). This is actually a long term project to build and fully commission.
- New components: Subharmonic capture cavity, fast tuner for 352 MHz rf cavities.
- Specifications: Subharmonic capture cavity at 58 MHz, 400 kV gap voltage (most likely require 2 cavities to get 400 kV).
- R&D required: Simulations of subharmonic capture/acceleration process to determine rf parameter tolerances. Design of 58 MHz, 400 kV cavity.
- Unknown aspects: Are two 58 MHz cavities needed to get 400 kV?

Commission fast ferrite tuner for rapid tuning of booster 352 MHz cavities, Goal is to be able to rapidly tune 352 MHz booster rf cavities for subharmonic capture project. This tuner should also allow better compensation of transient beam loading at injection for top-up operations. This tuner would also have application to the SR rf cavities.

- Present status: Presently being studied as an R&D project by the rf group.
- New components: Tuner mechanism.
- Specifications: To be determined.
- R&D required: Determine the exact tuner speed (bandwidth) and tuning range.
- Unknown aspects: Highest usable tuner bandwidth and tuning range in a 352 MHz booster cavity.

Upgrade the PAR kickers, This upgrade will allow PAR to operate at its design energy of 450 MeV. This has a number of advantages: 1. The booster dipole has much better current regulation when injecting at 450 MeV (factor of 2 in dI/I), 2. The PAR needs to be a robust back for subharmonic capture and rf guns for at least the next few years, 3. Faster damping in the PAR would allow more flexibility tuning 12^{th} harmonic rf system for bunch purity, 4. Future PAR experiments can take advantage of its full design energy, 5. This upgrade will allow LEUTL to interleave at up to 450 MeV without having to increase the PC gun charge/pulse to ~3 nC/pulse required for top-up.

- Present status: Deferred Nov 2001 (ASD spec 2001-021).

- New components: Kicker components, power supply components.
- Specifications: Scaling from 325 MeV kicker/septum setpoint values with DC corrector bump to 450 MeV (assuming the same DC corrector bump) the following table lists the required kicker/septum setpoints:

Kicker/Septum	***Injection Setpoint (kV)***	***Extraction Setpoint (kV)***
P1IK	19.4	27.4
P2IK	24.2	27.4
P4EK	-	27.4
PISP	532	540

- R&D required: Kickers/Septum magnets and power supply tests at higher setpoints. Septum should be evaluated for performance/damage at the higher setpoints.
- Unknown aspects: Fundamental and 12^{th} harmonic system performance needs to be benchmarked and re-evaluated for 400 - 450 MeV operation (design peak gap voltage is 40 kV for fundamental and 30 kV for 12^{th} harmonic rf). At < 400 MeV the injectors lose linac redundancy where injectors can fill SR without L4 or L5. Exact energy depends on L2, L4 and L5 performance and bunching chicane position.

BTS transport line upgrade, Modify BTS line and add three screens in order to make emittance/beta function measurements and do optics matching. Experimental matching will improve SR injection efficiency for reduced vertical acceptance due to long straight sections, matching future low emittance SR lattices (< 1nm) and matching different booster lattices. The three screen measurement will have fewer systematic errors compared to the quad scan method.

- Present status: The three screen measurement and matching software has already been implemented in the linac after the bunching chicane and PAR bypass.
- New components: 5 quadrupoles, 3 high-resolution screens, more steering magnets (1 spare BTS quad, 3 spare BTS quad coils, 1 BTS spare quad core, 3 spare booster quadrupoles presently exist).
- Specifications: Ability to match from different booster lattices to different SR lattices. Resolution for screens is around 10 μm and possibly lower for the center screen (Driven by small vertical spot sizes ~50 μm). Remeasure new quads as well as all quads downstream of second dipole since these will be used for matching. Need both YAG and OTR screens depending on charge.
- R&D required: Matching to different booster/SR lattices. Optics to match from booster to SR in case a BTS quad/quads fail. Mostly simulation work. Need to measure OTR signal as a function of charge.
- Unknown aspects: None.

Longer-term improvements and upgrades:

Realign Booster, This request is to compensate for rf drive frequency increase due to Decker distortions in the storage ring. It will improve response linearity for horizontal bpms with large orbit offsets due to dispersion. It will also improve lattice linearity by centering the orbit in the sextupoles.

- Present status: Data was taken in April 2002 and show that the booster circumference is 1.84 cm too big.
- New components: None.
- Specifications: Move 2 booster quadrants (1,2 or 3,4) toward rf cavities by 0.92 cm or all 4 quadrants by 0.46 cm.
- R&D required: None.
- Unknown aspects: Can the vacuum chambers be moved the same amount as the magnets? Indications are that there is just barely enough adjustment to move the chambers the required amount.

Accumulate beam in the booster, Idea is to achieve more uniform top-up by filling many SR bunches at once (5 to 10). Requires a kicker bump at the booster IS as well as redesign of the booster and PTB lattices near the IS. It also requires redesign of the booster main ramped supplies to allow arbitrary ramps (porches, plateaus etc). For accumulation, one could reduce demands on main ramped supply current regulation by going to 1 Hz (or lower) operation. As an example, with 58 MHz (6^{th} subharmonic) capture, the booster could be filled every 9^{th} bucket and fill 8 bunches and still preserve 153 ns bucket separation required for timing experiments. The SR injection kickers and booster extraction kicker would need a longer ~ 1.2 μs flattop.

- Present status: Long term idea at this point.
- New components: Two kickers, new current regulator hardware/software to allow for arbitrary (within limits) ramps (porches, plateaus etc). Modify SR injection kickers and booster extraction kicker to have ~ 1.2 μs flattop.
- Specifications: To be determined.
- R&D required: Booster IS lattice redesign, PTB lattice redesign.
- Unknown aspects: Idea needs to be developed further. For example, one could use this mode to accumulate a single high charge (subharmonic) bucket and operate the booster as the PAR presently operates.

Booster low emittance lattice, Reduce the emittance to ~10 nm at 7 GeV for ultra clean injection into future < 1 nm low emittance SR lattices with small dynamic aperture. Other ideas include using the low emittance booster as a source of beam for testing undulators at high energy and to make the booster a light source.

- Present status: M. Borland worked out a lattice using pole face windings in the existing booster dipoles to effectively double the number of fodo cells and reduce the emittance to ~10 nm.
- New components: New dipole magnets with gradient or high-current pole face

windings for existing dipoles. Skew quadrupoles to reduce coupling. Completely new lattice for light source idea.

- Specifications: ~10 nm emittance for SR injection. Light source lattice to be determined.
- R&D required: Need to add straight sections to Borland lattice, analyze injection and chromatic correction for the Borland lattice. Completely new lattice for light source application.
- Unknown aspects: Chromatic correction for SR injection booster lattice. Light source lattice needs to be worked out in detail.

Radiation effects facility in the BTX transport line, Study radiation damage effects on various materials using the 7 GeV booster beam. Can be used to study radiation damage effects from (near) injection energy to 7 GeV. Completed basic physics design of new BTX transport line with sample target positioned immediately upstream of the booster beam dump.

- Present status: Basic physics design of BTX transport line completed. Rough cost estimate completed.
- New components: 3 BTS quadrupoles, 2 new pulsed dipoles 0.5 T, 0.1 m, 2 bpms, 2 flags 1 BTS type current monitor.
- Specifications: Raster capability of dipoles. Beam size adjustment using quadrupole triplet.
- R&D required: None.
- Unknown aspects: None from accelerator physics considerations.